A PHILOSOPHICAL ASPECT OF SCIENCE.

ONE of the earliest and most persistent efforts of the human mind has been that of finding some common basis in things, some receptacle to catch the stream of change: days and nights, this world, other worlds, life, death, decay, regeneration. To us it would be intolerable to accept the idea of a sieve-like universe, through which events poured into some inaccessible limbo, never to be recovered again. We expect things to be related, held together somehow, somewhere, in spite of apparent disruption, disappearance, or total loss.

On this expectation rests the whole procedure of knowledge, which for purposes of illustration I propose to confine to that involved in scientific methods.

Let us start with an experience. A certain combination of events gives me pain. Deep-seated in my organism is dread of pain and roughly speaking and in crudest terms, I am a being composed, for survival-fitness, of three factors: horror of pain, desire for pleasure, and some power of self-adjustment. Hence a painful experience is not merely suffering, but also learning; in striving to avoid, I strive to change the conditions of my world, and my will, however puny, is exerted to that end.

How much I manipulate it depends on my own structure, imagination, will. To a creature devoid, e. g., of locomotion, the range of adjustment is restricted. Almost passive, it suffers and succumbs, or chances to survive; but its range of pleasure, pain, or curiosity is limited as

well. The more complex the organism, the more complex the world of its reactions, interpretations and experiences. For instance, a burnt child dreads the fire, but its simple soul is satisfied to avoid the fire; it has as yet conceived no ambition to explore the mysteries of heat, of atmospheric pressure, and molecular activity!

These elementary remarks may introduce my thesis. I propose to urge: (1) that the accumulation of knowledge, the intricate structure of science, is ultimately for this purpose,—as far as may be to order and control life, and (2) that in so far as its formulations have achieved their aim, it has been by the use of abstraction. Incidentally we shall see how the naive mind is apt to accept these formulations as true in a sense which science is not concerned to assert, and which it could never achieve;—I mean accepts them as actual records of what is believed to be the real world, and revelations that reproduce the intimacies of Being.

But lest I should range over the whole field of knowledge let me restrict myself to the fortunes of some scientific hypotheses; and finally let me ask if truth in the above sense can ever be arrived at by science, and whether a decision in the negative necessarily amounts to skepticism.

You may remember the old Greek story of the atheist Diagoras, when he was shown over a temple to Poseidon, full of the olive offerings of sailors whom their prayers had saved from shipwreck. Unabashed he turned and said: "Show me rather the offerings of those who prayed and perished."

Is not our admiration for the successes of science somewhat similar and are not its failures erased from the records of its triumphs? Has it not as persistently disappointed the human craving for finality as the wildest fancies of philosophy? At how many points in its development have we not been tempted to think, "Here is finality,

here is the key to the inmost shrine," and found that we were still wandering in the antechambers of the labyrinth?

Let us briefly review the vicissitudes in the history of "matter." Newton defined matter thus: "It seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable, movable particles...and that these primitive particles being solids are incomparably harder than any porous bodies compounded of them; even so hard as never to wear or break in pieces, no ordinary power being able to divide what God himself made one in the first creation." Thus atoms were absolutely inelastic, and according to the theory of essential disparity of matter and motion, they were *inert*. A third character, absolute *homogeneity*, was a necessary conclusion from the fact that all bodies, of whatever they were composed, were acted upon by gravity in exactly the same manner. Thus we have particles which are mathematically though not physically divisible, absolutely solid, inert and homogeneous.

Many experiments justified this definition. Did all? First, according to the kinetic theory of gases, solidity is impossible. In collision of ordinary bodies or particles, the practical loss of apparent motion is accounted for by the conversion of an unchanged quantum of energy into an internal agitation of the minute parts composing the colliding bodies. Atoms are by definition destitute of parts, hence in a collision of atoms, no such compensation is possible, and the physicist is faced with the alternatives, either of denying the solidity of atoms in the Newtonian sense, or of renouncing the principle of the conservation of energy. The first is preferred. To make a long story short, Newton's rigidity of atoms, like his theory of contact action —the only thoroughly mechanical explanation of the operations of one body upon another—proving inadequate, his mechanical atoms were replaced by dynamical ones.

As defined by Boscovich and the French School, an atom is no longer a substantial entity, but a mathematical point, a center of force, and "matter" is a crowd of such points, endowed with inertia and powers of attraction and repulsion.

Now the difficulty which beset Newton's theory of contact action, viz., how to explain "action at a distance," forced from him a descriptive apparatus, setting forth the behavior of related bodies, but not attempting to explain it. On his own atomic theory he could not do so. This apparatus was by Boscovich taken for reality;—he thus precisely inverted Newton's procedure. In Professor Ward's words, "The solid, primitive particles of various sizes and figures in which Newton believed, were rejected; and the inherent forces acting through a vacuum which he disclaimed as absurd, were accepted as the reality to which all the physical properties of matter were due."

But this inversion of the purely mechanical theory again raised difficulties. For to the "mass points" were attributed intrinsic force, a departure from the fundamental idea of the indifference of matter to motion, and also from the conception of force as something arising only in the relation of two bodies, not present in one alone.

Lord Kelvin's theory of vortex atoms was an endeavor to combine the mechanical and dynamical. Again to quote Professor Ward, "There is (in the kinetic theory) no action at a distance, but then there is no empty space: action and reaction are to be explained, not by impact, but by the physical continuity of the plenum. There are no hard atoms; yet the atom occupies space, and is elastic in virtue of its rotatory motion."

I must not spend much more time on this development of the new upon the almost total wreckage of the old. I will merely add that Kelvin's theory is moribund, too. For his theory called for a "homogeneous, incompressible, perfect

fluid" in which vortex atoms are rings formed by rotational movements. But how can mere disembodied motions possess inertia? As Maxwell says, "Though the primitive fluid is the only true matter according to the kinetic ideal ....yet that which we call matter is not the primitive fluid itself, but a mode of motion of that primitive fluid. In [this] theory, therefore, the mass of bodies requires explanation. We have to explain the inertia of what is only a mode of motion, and inertia is a property of matter, not of modes of motion."

To return once more to the older view of atoms, the theory of the homogeneity of matter issued in the definition of its parts as in all respects equal, viz., the atoms themselves remain as elements utterly devoid of finaltiy, or in Spencer's words, "The properties of the different elements result from difference of arrangement, arising by the compounding and recompounding of ultimate homogeneous units." But the science of chemistry is a denial of this, as we know. And what occupies the scientific field to-day as a theory of matter?

The old atom, either as a physically irreducible particle, or a point of force, has disappeared. In its stead there is a minute system of electrical charges, called electrons, positive and negative, say 68,000 of these constituting one atom, and separated by what is analogous to interstellar, interplanetary space. As Sir Oliver Lodge picturesquely puts it, the relative sizes of electron and atom may be gathered from this: Imagine an electron of one inch in size, your atom would be a mile and a half in diameter!

If Newton's atoms were imperceptible, these elemental and infinitely smaller bodies almost stagger the imagination. And with their advent for various reasons there comes again a disturbing doubt as to the validity of well-established scientific principles, such as conservation of

energy, and conservation of mass. But perhaps I have given concrete illustrations enough to show how over and over again the most fundamental "truths" of science have been superseded, buried under fresh growth.

Two points have perhaps been noticed:

1. The increasing tendency of science to recede in its formulations, from anything which could conceivably be a matter of actual sense experience; starting with solid particles, as a description of the basis of things, it tends to strip these of perceptible characters and to melt and fade the living, qualitative world into a mathematical scheme which is purely quantitative and abstract.

2. The fact that, in spite of this tendency, science is no mere cobweb of finely spun speculations, but is sharply checked and corrected by the very sense experience it apparently ignores.

How are these apparently contradictory facts compatible?

Science is no idle game, its unwearying speculations are inspired, sustained and tested by a single purpose, that of harmonizing and controlling life. This purpose may be defined from various points of view: e. g., from the esthetic, which rejoices in an interrelated and orderly system of thought; or the practical which seeks the ability to reproduce experiences, to widen the scope of life, increase the complexity of its relations perhaps, but above all to maintain existence with some degree of harmony and security.

Therefore science is justified if its methods succeed in realizing this ideal. The savage with his untutored mind, his superstitions, his investing of nature and the elements with erratic and wild powers, falls short of such security as we seek to possess. He knows his own capricious self, and his consistently anthropomorphic imagination attrib-

utes to his world just such caprice, — it is revengeful, changeable, wild, like himself.

But science de-humanizes the world. Whereas, in our indecisions, our caprice, our fluctuating wills, we are not unlike the savage still, yet our world, *for science,* is purged of all passions, all chance, all uncertainty. There is no minutest particle of matter, no faintest pulse of energy but is held or moved according to fixed immutable law. If e. g., an astronomical calculation is discarded, it is not because we suspect the solar system of capricious behavior, but ourselves of superficial observation, or mistaken interpretation. The great world stands fast in the absolute regularity of law, while we try again and again to formulate its secret.

But herein lies the strange paradox of science—we *control* life only by the partial abstraction from life. Science must abstract, in order that we may argue from one case to another. The abstract law which omits all the particular circumstances of every fact gains thereby applicability to fresh fact. The more phenomena it can relate under one law, the more successful is the law, and the permanence of any law is in direct proportion to its universality (cf. Poincaré on "Laws and Principles").

Suppose a given experiment *x,* in which there are a thousand factors, the influence of the stars, known and unknown, the light of day, the atmospheric conditions, actual governments among men, the various religions, etc., elements uncountable, and yet present. What does science do? The elimination of the irrelevant being its ideal, it clips and clears and ignores, till perhaps just one element remains, e. g., *weight.* The falling body *x* will move after one second, with an acceleration of 32 feet per second.

Another experiment is made,—with a totally different body *y.* Meanwhile the earth has whirled away through space, the daylight has gone, the stars in unfathomed re-

cesses of invisibility have changed their relation to our world, every element known and unknown is different in however slight and subtle a way; and yet, for gravity, body y falls to the earth exactly as did body x, there is no faintest fluctuation of inexorable sameness. For it a rock is precisely the equivalent of a living organism.

Look again at the history of science. Which have been the unstable hypotheses? Those which deal with more or less unimportant details of internal structure or with any subsidiary phenomena. As I have said, the more general and simple a so-called law is, the more is its permanence guaranteed, until like that of the conservation of energy it is put out of the reach of criticism, and is no longer a "law." but a "principle."

Scientists use every trick and expedient to leave this undisturbed. As it has been well put, "we postulate an *unknown supplement* of the experienced, in order to prevent facts from refuting a cherished assumption." Let me quote Professor Thomson: "In electrical phenomena we are brought into contact with cases of interaction between bodies charged with electricity, in which the action of the first on the second is not equal and opposite to the reaction of the second on the first. In such cases we suppose that both bodies are connected with the ether round them, and that Newton's third law holds when we consider the ether and the two bodies as constituting the system under examination. From this point of view, the potential energy of an electrical system may be regarded as due to its connection with an *invisible subsidiary* system, possessing kinetic energy equal in amount to the potential energy of the original system."

This is what I began by describing as a *receptacle* for all phenomena, a confine within which minor disturbances may be expected, but which itself is beyond the reach of such disturbance. I do not withdraw my assertion that

science is checked by sense experience, and in minor matters it is constantly being transformed. But sense experience is aided and harmonized by nothing so effectively as by these more general principles. Hence we refuse to quarrel with their bleak and lifeless abstraction. We see then how such apparently disrespectful juggling with so-called "fact" is justified. It is justified because it allows us to reproduce, modify, predict, certain groups of experiences at will, and this is the supreme end and aim of science: control.

Look at what Aristotle called the ἴδιαι ἀρχαί, or special principles of the sciences. According to him they were irreducible to one another, and we have not disproved his contention. Biology and physics do not wholly agree. Euclidean space and non-Euclidean or curved space each possesses its special space-relations, and axioms in the one system become absurdities in the other. A more intimate instance is this,—the atomic hypothesis as to the nature of matter is not reducible to a mathematical hypothesis, yet they both lead to successful manipulations of the real. In our theoretical world the lion and the lamb lie down together; so long as the various theories succeed in controlling those portions of our experience assigned to them, why should we be over-particular in a demand that they shall all be convertible into the same formula or hypothesis?

You will remember that I spoke of Newton's atomic theory as having "proved inadequate." I hope I have made myself clear as to what I mean by that word. A theory may be beautifully consistent with itself and yet be inadequate in the sense I have tried to describe. Let me add another illustration. A theory is not discarded out of mere caprice; like the Ptolemaic system, a formulation may work perfectly well until a widening experience brings in so many fresh factors that any calculation which includes

them becomes too cumbersome for convenient use. Then is the moment for such scientific upheavals as that involved in passing from the Ptolemaic to the Copernican system. The facts observed and classified in the old order yesterday, assemble to-day under new names and with reversed rank. Yesterday the earth was central, to-day the sun is the point of reference for the whole solar system. Nothing has fallen out of the heavens; the planets and stars remain in their old places, but we describe their relations differently, and this altered description is forced from us by their behavior. The alteration justifies itself, because it enables us to calculate and predict with increased facility and success.

The first two objects of this paper I have laid before you:

1. The fact that scientific procedure is purposive, its end and justification, control of our experience.

2. And that to attain this control it must be abstract, eliminating whatever is irrelevant to the special purpose in view.

Finally I proposed to ask whether science can be said to penetrate into the very heart of Being,—reproducing its true nature?

Let us put the question in this form: Is it true that in the objective world which goes on its way more or less regardless of me and my science, is it literally true that there are atoms, electrons, perfect fluids, ethers, etc. etc.? It seems to me there is only one answer: we do not know; we know no more than the merest savage. By a curious paradoxical trick, we have so defined our world as to put it quite beyond the reach of refutation by sense-experience. We assert of it, and minutely describe parts of whose individual nature we can never, *ex hypothesi,* have actual sensible experience, as of one individual with another.

Suppose a solar giant with short sight who required a

crowd composed of nearly all the inhabitants of Europe before he could even see it at all. He might by some happy guess suggest that its black mass was composed of atoms, but how far would you as one of the component atoms admit that this giant really knew anything about you?

For science treats of bare averages, and we know not how far the exactness of its (minor) laws would go unchallenged if they took account of individual changes among infinitesimal bodies.

Think of how peculiarly erratic we are in our methods. We so define the real constitution of matter as to shut ourselves out from any possible knowledge of it, in the sense I have tried to describe. We lay down the law of the conservation of energy, let me say arbitrarily, and this law is based on what assumptions? First, that from our tiny corner of this immense world, we can by analogy infer with accuracy the nature of all the vast remainder; secondly, that the tiny corner plus the vast remainder together possess a certain finite though unknown sum of energy, and that this sum is absolutely constant. By what right do I make such assumptions? Take another instance. Although the law of causality is gradually being extruded from science which more and more contents itself with mere description, it still has a very respectable reputation. But is it an accurate law? What it asserts is this: reproduce all the conditions of a certain phenomenon, that phenomenon will reappear. But the conditions never can be reproduced, not in countless billions of cycles; for admitting the bold assumption that almost every factor can be reproduced, the conditions would at any rate be assembled in another time. And by what right do we assume that another time has no effect upon the rest of the conditions? none upon the resultant phenomenon? Strictly speaking by no right whatever.

There is another disheartening weakness of science:

do what we may we never seem to know the thing examined, in its very intimacy,—everything is ultimately defined by what it does to something else. Mass is defined in terms of force, force in terms of mass. Space is relative, so is time. Motion is known not as absolute, but as something which arises out of relation. Body A might whirl away through empty space for ever and not be in motion in the sense of perceiving it, or being perceived as moving. Add body B, whirling faster or slower, and the phenomenon of motion emerges.

Of space Poincaré says: "It is impossible to imagine pure empty space. . . ."; "whoever speaks of absolute space, uses words devoid of meaning. . . ."

"For example I am at a certain point in Paris, the Place du Panthéon, and I say I will come back *here to*-morrow. If I am asked, do you mean you will return to the same point in space? I shall be tempted to answer 'Yes'; and yet I should be wrong in saying so. For between now and to-morrow the earth, carrying with it the Place du Panthéon, will have traveled more than two million kilometers. If I wish to be precise, this fact does not help me. For these two million kilometers have been traveled by our earth in relation to the sun. The sun again is in motion relatively to the Milky Way, and the Milky Way itself is doubtless moving though with a rapidity inaccessible to our knowledge. Thus we are in complete ignorance, and shall always be so, of exactly how much the Place du Panthéon moves in one day. What I should say is this: To-morrow I shall again see the dome of the Panthéon, and if there were no such dome, my phrase would be meaningless and space would vanish."

He gives another illustration, that of Delboeuf:

"Suppose that in one night all the dimensions of the universe increased one thousand times, what would be my sensations the next morning? I should be aware of no

change whatever. For all the relations of one thing to another would have retained their precise proportions, and I should remain forever in ignorance of this titanic transformation."

I hope all these examples have not been confusing. I have merely tried to point out that to serious thought it is impossible to accept naively the concepts of science, accept them I mean as the true counterparts, in thought, of what goes on in the real objective world.

It cannot be put better than by Prof. Thomson, in his brilliant dictum, "Scientific theory is a policy not a creed." Must we turn skeptics, must we believe that all effort really to know is futile, bound to ultimate failure? I think not. Let us forget all that we have been criticising for a moment, and simply see what really takes place, when in the light of scientific directions as to temperature, atmospheric pressure, etc., I try to boil an egg. I may need the latest refinements of physics to effect my purpose, but they are ultimately tested by the fact that my egg *does* boil, and that their use leads to a satisfying breakfast.

All I wish and need is to carry out my purpose. If I find it easier to bring about a desired complex of relations by treating my world *as if* it swarmed with electrons, then I say "it is constituted thus." But I need not believe the electrons in my scientific imagination have a real counterpart *in what actually goes on.*

If I can penetrate into the universe by these methods, then we may say in a very profound sense, that we do understand it. Our formulations will forever fail if we demand of them actual reproduction of the unending richness and complexity of even our minute plot of this unmeasured universe. They will not fail, if we understand that they are instruments and symbols and not reproductions, and ask of them only assistance in harmonizing and integrating our experience. And so the lesson of the in-

stability of scientific theories is not necessarily a skeptical one, and at the risk of repetition let me emphasize this point. I say that the transformations of scientific theory do not necessarily lead to skeptical conclusions. And why? For two reasons: First, because they are not random, but *progressive,* because they always mean more successful control of experience; secondly, because they are not merely capricious and fanciful, but *rather are forced from us by the world with which we deal.* Though it is sometimes friendly in allowing our intimacy, amiable in appropriating some of our interpretations, it is merciless in punishing stupidity, and with "nature" ignorance is crime. The punishment is always a signal for a readjustment of what hitherto we have asserted as true.

The progress of science might be described as a series of successes and failures on an ascending curve. No failure means a total collapse of knowledge, no success is ever complete. But the proportion of success to failure is encouraging and allows us to conclude that the outer world of reality is not beyond the measure of our understanding. But if we are not led to skepticism neither are we given absolute certainty. There is no incontrovertible proof that the sequences of nature, of days and nights, or of our own thoughts as we know them, will ever return.

The two main types of mind in the world, the optimistic and pessimistic, will emphasize the one fact or the other, the successes of yesterday, or the uncertainty of to-morrow. Meanwhile science lives by constant readjustment, finding in its growing success and control the hope, no matter how distant it may be, of some ultimate consummation.

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